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Texture-taste interactions: Enhancement of taste intensity by structural modifications of the food matrix

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Abstract

The reduction of salt and sugar in food products remains a challenge due to the importance of those ingredients in providing a highly desired taste quality, enhancing flavor, determining the behavior of structuring ingredients, and ensuring microbiological safety. Several technologies have been used to reduce salt and sugar content in foods such as replacement of sugar by sweeteners, replacement of sodium salts by blends of other salts, taste enhancement by aromas and taste boosters or gradual reduction of sugar and salt in small steps over time. In this study we present two alternative approaches to enhance taste perception. First, the use of an inhomogeneous spatial distribution of sugar in food gels is introduced as a way to enhance sweetness perception [1]. The translation of the concept of taste contrast to bread applications is discussed which allows to reduce salt content in bread by 25% without loss of saltiness intensity and without addition of taste enhancers, aromas or salt replacers [2]. Secondly, it is demonstrated how the serum release under compression of mixed polysaccharide/protein gels can be engineered to enhance sweetness perception. An increase of serum release by 5x allowed to reduce sugar content of gels by 30% while maintaining sweet taste intensity [3]. The translation of this concept to low salt sausages is discussed. Sausages were engineered to exhibit enhanced juiciness which lead to a boost of saltiness allowing for up to 40% salt reduction [4]. These approaches can be used to further optimize the development of products with reduced salt and sugar content while maintaining taste intensity.

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Keywords: Salt and sugar reduction; food texture; taste contrast; serum release; taste enhancement

1. Introduction

In recent years, concern has grown about the association of dietary practices to the development of health problems. In this context, a decrease in sugar and sodium intake has been recommended to

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diminish the incidence of obesity, dental caries and cardiovascular diseases caused by high blood pressure. Sugar and sodium reduction remains a challenge for food manufactures, as it generally leads to changes in the overall quality which may compromise consumer acceptance. Different strategies have been proposed to reduce sugar and sodium content of foods. One strategy is to replace sugar by high potency sweeteners and sodium salts by blends of other inorganic salts such as potassium chloride and magnesium chloride. Another reduction strategy is the addition of taste enhancers which amplify the taste intensity. An alternative approach to reduce sugar and salt content is by gradual reduction of the sugar and salt content over a longer time period, typically months or years. However, reduction is limited since it requires industry-wide cooperation and long time periods to achieve significant reductions. Therefore, other means to reduce the sugar and salt content in food and beverages are desired.

In this study we present two alternative approaches to enhance taste perception by structural modifications of the food matrix. The first approach is to generate an uneven spatial distribution of tastants such as sugar and salt in the food matrix leading to taste contrast which gives rise to taste intensity enhancement. The second approach is to engineer the microstructure of the food matrix to enhance the amount of serum which is released from the matrix upon mechanical compression such as chewing. As tastants need to be dissolved and delivered to the taste buds in order to trigger a response, enhancement of serum release in the food matrix is a tool to effectively release and deliver tastants. The applicability of both approaches to real foods is discussed using examples from bakery and processed meat applications, respectively.

Meiselman and Halpern showed [5] that the delivery of continuously alternating concentrations of aqueous salt solutions enhances saltiness intensity compared to model salt solutions with the same overall salt content but delivered in a non-alternating fashion. Their results indicate that the presentation of contrasting salt intensities can be used to enhance taste intensity. In this study, we show that taste enhancement in semi-solid gels can be achieved by an inhomogeneous spatial distribution of tastants, which might lead to a discontinuous stimulation of taste receptors [1]. Semi-solid model gels exhibiting an inhomogeneous spatial distribution of sucrose were prepared by placing four layers of mixed agar/gelatin gel containing different sucrose concentrations on top of each other. The sweetness intensity of all samples was evaluated by a panel consisting of naïve subjects. We demonstrate that taste enhancement through sensory contrast can be achieved by alternating sucrose concentrations in the mouth temporally and spatially in semi-solid model gels under realistic eating conditions. The concept of taste contrast is also applied to bread applications [2]. It is shown that an inhomogeneous distribution of salt in bread can be used to enhance saltiness intensity allowing for reduction of salt of more than 20% without loss of saltiness intensity.

Semi-solid gelled food products are generally complex products containing different ingredients, such as proteins, carbohydrates and fats. Mixed or composite products comprising both proteins and polysaccharides are sensitive to phase separation. In cold-set whey protein isolate (WPI)/polysaccharide mixed gels minimal variations in the type and concentration of the polysaccharide result in a wide range of microstructures. The microstructure of the mixed gels strongly affects their large deformation and sensory properties. The occurrence of serum release from WPI/polysaccharide gels is of importance with respect to the perception of tastants. Serum release can be related to the juiciness perception in fruits, vegetables and meat products. The phenomenon of serum release is mainly dominated by the microstructure of the gel, whereby gels with bicontinuous microstructure show the highest amount of serum release upon compression [6]. As tastants need to be dissolved in saliva before they can be perceived by the taste buds, serum release is likely to improve this process and enhance the perception of tastants in gelled products. In this study we show that serum release from cold-set mixed gels can enhance the perception of tastants. A set of mixed WPI/gellan gum gels with controlled serum release, constant large deformation properties and different sugar concentrations was prepared [3]. It is shown that serum release boosted sweetness intensity significantly. The translation of this concept to low salt sausages is discussed. Sausages were engineered to exhibit enhanced juiciness which lead to a boost of saltiness allowing for up to 40% salt reduction. These approaches can be used to further optimize the development of products with reduced salt and sugar content while maintaining taste intensity [4].

2. Materials and Methods

A detailed description of all materials and methods used in this study can be found at [1-4].

3. Results and Discussion

In this study we present two alternative approaches to enhance taste perception by structural modifications of the food matrix. The first approach is to generate an inhomogeneous distribution of tastants such as sugar and salt in the food matrix leading to taste contrast. The second approach is to engineer the microstructure of the food matrix to enhance the amount of serum which is released from the matrix upon mechanical compression.

In the first approach, model systems consisting of layers of mixed agar/gelatin gel were used to investigate the effect of the spatial distribution of sucrose on perceived sweetness intensity [1]. 2-Alternative forced choice tests were performed with consumers to compare the sweetness of layered samples with an inhomogeneous distribution of sucrose to the sweetness of a reference sample with a homogeneous distribution. All samples had the same overall sucrose concentration (10%) and similar mechanical and rheological properties. Consumers perceived the samples 40/0/0/0, 40/0/40/0 and 12/12/12/12 significantly sweeter than the reference 10/10/10/10 (numbers denote the sucrose concentration wt%/wt% in each layer) ($k = 144$, $p < 0.05$; $k = 195$, $p < 0.001$ and $k = 178$, $p < 0.001$, respectively; at $l = 0.5$, $n = 256$) (Figure 1). No significant differences in sweetness were observed between samples 15/5/15/5 and 20/0/20/0 and the reference 10/10/10/10. This demonstrates that an inhomogeneous distribution of sucrose enhanced the sweetness intensity of layered gels, but large concentration gradients of sucrose are necessary to achieve a significant sweetness enhancement. Figure 1 shows the positive effect of sucrose concentration gradient level on the proportions of selections of inhomogeneous samples. Sample 40/0/40/0 displayed the largest sweetness enhancement, as indicated by its high proportion of selections. The sweetness enhancement of this sample was even higher than that of the homogeneous sample 12/12/12/12, which contained 20% more sucrose. Therefore, an inhomogeneous spatial distribution can compensate for an effective sucrose reduction of about 20%.

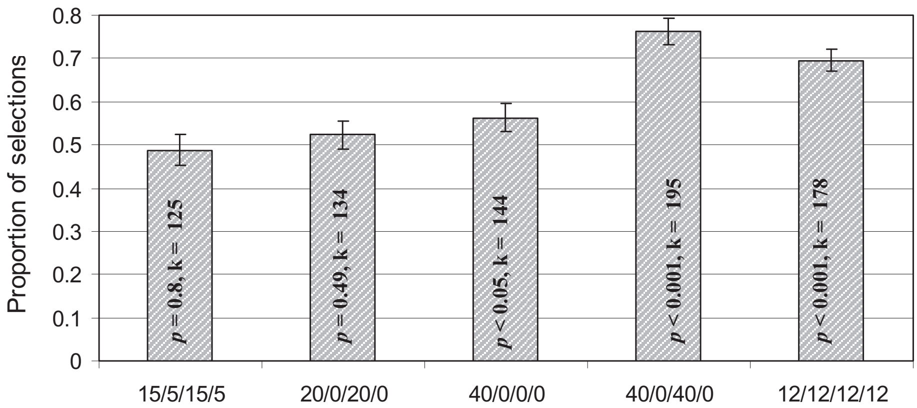

Fig. 1. Proportion of selections (±SEM) of inhomogeneous samples over the homogeneous reference 10/10/10/10 in the 2-AFC tests. Numbers denote the sucrose concentration wt%/wt% in each layer. p-values are calculated by binomial test of k ($n = 256$, $l = 0.50$) [1]

Based on the findings that taste contrast in semi-solid model gels can be used to enhance sweetness perception, we followed the same approach and translated it to bread applications [2]. Breads were prepared by sheeting dough varying in salt levels and stacking in an alternating fashion. In this way, a horizontal laminated bread dough was obtained in which the layers contain either all the same salt content (homogeneous distribution, contrast ratio 1:1) or which has alternating layers of high and low salt content (heterogeneous distribution, contrast ratio 1:9 to 1:11). A consumer panel was performed to evaluate the influence of the total salt concentration and the spatial distribution of salt in bread on saltiness perception. Figure 2 summarizes the saltiness intensity of breads with either homogeneous or inhomogeneous salt distributions at different overall salt levels.

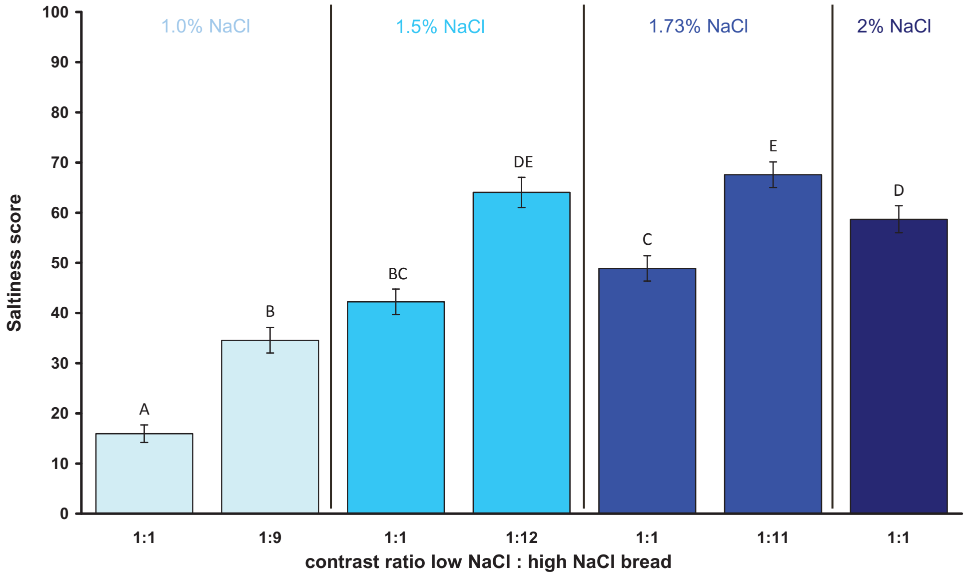

Fig. 2. Saltiness intensity of breads scored by a consumer panel. The overall salt concentration is indicated above the columns. The error bars indicate the mean SEM. The letters above each column indicate the grouping according to Tukey HSD at $\alpha = 0.05$. Columns with the same letter were not significantly different [2]

At all salt levels, heterogeneity of the salt distribution in bread enhanced the perceived saltiness significantly. At 1.0% NaCl, the heterogeneous spatial distribution of salt caused a significant relative increase of saltiness intensity by 117% (from 15.9 to 34. 6). At 1.5% NaCl, a significant enhancement of saltiness was found from 42.2 to 64.1 corresponding to a relative increase of 52%. The taste intensity of the sample with an overall salt content of 1.5% with a heterogeneous distribution was perceived slightly saltier than the reference sample of 2.0% salt. The saltiness ratings of these two samples were not significantly different. This indicates that a salt reduction by more than 25% can be achieved without loss of saltiness by means of an inhomogeneous spatial distribution of salt. At 1.73% NaCl, the concentration contrast enhanced saltiness ratings from 48.9 to 67.6, corresponding to a relative increase by 38%. This heterogeneous sample was significantly saltier than the reference of 2.0% salt. These results demonstrate that an inhomogeneous distribution of salt in bread can be used as a tool to lower sodium content while maintaining saltiness perception.

In the second approach, the microstructure of the food matrix was engineered to enhance the amount of serum which is released from the matrix upon mechanical compression to increase taste perception. To investigate the effect of serum release on taste intensity, a set of mixed WPI/gellan gum gels with controlled serum release, constant large deformation properties and different sugar concentrations was prepared [3]. The microstructure and serum release of gels with increasing gellan gum concentration was determined using Confocal Scanning Laser Microscopy (Figure 3). Increasing the gellan gum concentration caused a remarkable change in the microstructure of the gels. The pores present in the protein network can be described as the phase volume of the immiscible polymers. At a gellan gum concentration of 0.025 wt% the microstructure of the gels was protein-continuous. Increasing the concentration of gellan gum to 0.04 wt%, i.e. increasing the ratio between the phase volume of the polymer and that of the protein, the microstructure became bicontinuous. The observed change in microstructure corresponded to a gradual increase in serum release. A further increase in gellan gum concentration had only a slight effect on both pore size and interconnectivity. Gellan gum concentrations higher than 0.065 wt% resulted in macroscopic phase separation: a layer of gellan gum appeared on the top of the gel.

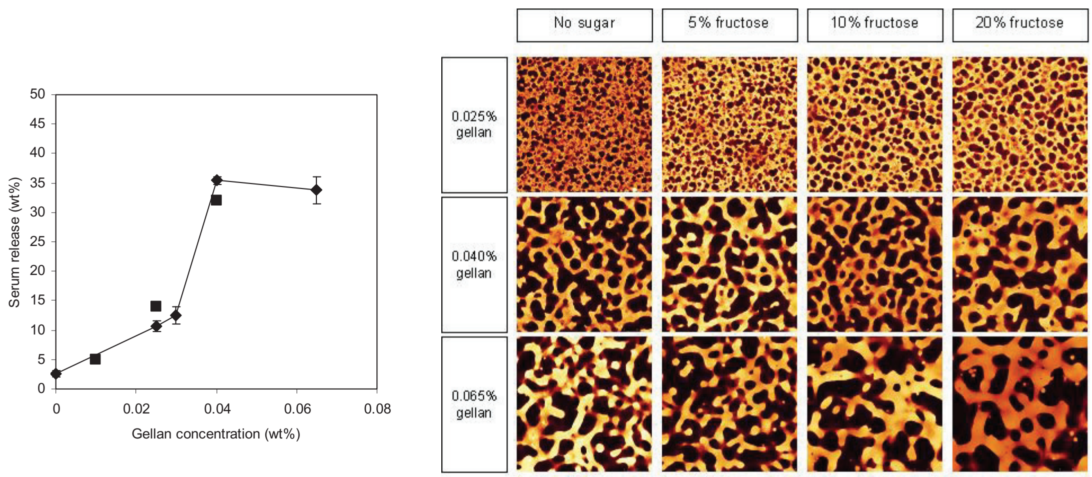

Fig. 3. Effect of gellan gum on the serum release (left) and microstructure of mixed WPI/gellan gum gels (right) (image size: 123 x123 μm). [3]

The sensory characteristics of the gels were investigated with the use of a sensory panel trained according to the principles of Quantitative Descriptive Analysis (QDA). For sensory attributes of particular interest, the relation between serum release, sugar concentration and score of the individual samples was highlighted. The scores for the mouthfeel attribute water release increased for gels with higher gellan gum concentration and slightly decreased with increasing sugar concentration (Figure 4). The observed trends for this attribute were remarkably similar to those of the measured serum release. The scores for the attribute sweet were significantly higher for gels with higher serum release. Increasing the serum release from 2 wt% to 35 wt% induced an increase of sweetness intensity by 30-45%. The increase of the scores was relatively larger at lower sugar concentration.

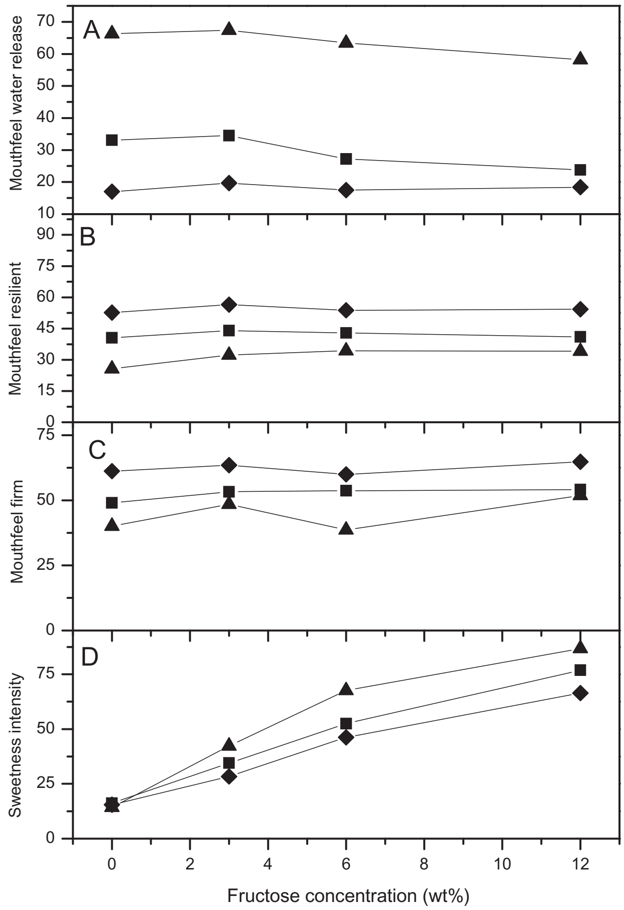

Fig. 4. Effect of gellan gum and fructose concentration on mouthfeel attributes water release (A), resilient (B), firm (C) and sweetness intensity (D) (•: 0wt% gellan gum; ■: 0.03%wt% gellan gum ▲: 0.04wt% gellan gum) [3]

Based on the results from mixed biopolymer gels, we investigated whether the addition of polysaccharides to meat batters can be used as a tool to enhance the release of serum under compression, which in turn would enhance juiciness and saltiness perception [4]. Therefore, a series of cooked sausages was developed that varied in salt content, added polysaccharide type and content. Cooked sausages were analysed by instrumental techniques for their physical properties and by a sensory panel to judge their sensory attributes. Sausages were obtained which varied significantly in the amount of serum which was released under mechanical compression. Sausages variants that show a high serum release in the mechanical analysis were perceived as juicier and saltier than the corresponding variants with a low serum release. Thus, serum release in sausages, and the accompanying juiciness, enhances the perception of saltiness.

4. Conclusions

An inhomogeneous distribution of sugar in gels and salt in bread can be used to enhance taste intensity allowing for reduction of sugar and salt without loss of taste intensity. The relative enhancement of taste intensity was largest at the lowest total tastant concentration. The magnitude of taste intensity enhancement increases with increasing sensory contrast. The principle of sensory contrast may also be applied in other (semi) solid food products and for other tastants enabling significant sodium and/or sugar reductions.

In mixed WPI/gellan gum gels with a low protein concentration, varying the protein concentration by keeping a constant protein/ polymer ratio allows to modulate the mechanical properties of the gels without affecting the serum release. The modulation of the serum release in food gels appears to be a powerful textural tool to enhance sweetness. Serum release in sausages, and the accompanying juiciness, enhances the perception of saltiness. Using this approach allows to reduce tastant levels without loosing taste intensity.

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